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Invited paper

The inventor Valdemar Poulsen

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Abstract

Valdemar Poulsen's famous inventions are adequately described in several books and articles while his biography in the literature is marginal. This paper assembles some humanistic highlights about the great inventor who was a very private person, may be more of a philosopher and a lover of life and art than just a technologist. His many awards and recognitions through his life attest to this. © 1999 Elsevier Science B.V. All rights reserved.

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Valdemar Poulsen, inventor of Magnetic Recording, was born in 1869 in Copenhagen, Denmark, the son of Jonas Poulsen, a lawyer, and Rebekka (born Brandt). They lived in an apartment on the street Landemærket, near the Kings Garden. His mother died very young, when he was only four years old. Poulsen writes 'My first sunlit memoirs are closely linked to the Kings Garden, where I came daily with my sisters under the care of a nurse or my parents. My most beautiful memoirs as a five years old were from that beautiful garden. I remember how thrilled I was by the statue of the trusting small boy that to this date unwarily forces the neck backward on the swan he seems created to ride (Fig. 1). Near that small water fountain that cleansed and cooled the air it one day happened that a stately lady came towards us. It was the Queen-widow and she asked the nurse: 'To whom does this charming boy belong?'. The nurse was very proud when she came home and reported this 'happening' and Valdemar would for many days proudly repeat for himself: 'Lovely Valdemar Polle'. The Queen-widow's appraisal was in some contrast to the silent and somewhat sulky manners he often displayed at home, where the shadow after his mother's death also still prevailed. And little was he to know that in 1939 he would encounter the royal family again by receiving a Danish medal of high order.

Valdemar developed a dislike for elementary school, which he found devoid of light and air, and of artistic or scientific matters. Everything that had to do with school was a suffering and his poor father had to make a change of environment three times; he finally became relatively happy in the school named Borgerdyden in an eastern district of Copenhagen (Christianshavn).

Valdemar was by no means a bookworm. He was only interested in physics, and devoted most of his efforts to that discipline. He studied physics so zealously that he was far ahead of his peers in that subject; before they started their textbook he was halfway finished with his. At home he carried out and built many of the devices and experiments. He thus constructed many electric devices and experimented with chemistry. He produced hydrogen by pouring acid onto zinc in an old ink well and observed with devotion the generation of tiny bubbles. Of course he also verified that the bubbles were hydrogen by igniting them with a burning match stick. He was thrilled by the tiny cracks from the explosions. His delight over such experiments was great and he would send for his whole family to demonstrate, for instance, the generation of a small electric arc, although it was only one millimeter long.

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Fig. 1. Statue of Boy with Swan, in the King's Garden, Copenhagen (Photo by author).

The experiments were at times dangerous as when he once filled a pig's bladder with hydrogen and squeezed it under his arm to get a real powerful blast of hydrogen. He ignited it with a burning match and with a loud bang the bladder and part of his sweater disappeared, fortunately without injury to his arm.

This singular interest in physics caused the other disciplines to suffer and his grade book was therefore pretty shabby, causing a tense relation between father and son every Saturday. The father tried to improve his grades by letting the son prepare his lessons in his study. This naturally led to the appearance that the boy was studying diligently while in reality his thoughts were far away, busily planning the next experiments in chemistry or physics. And the minute the father left the room he would turn to his favorite pastime: he would borrow his father's lacquer stick for sealing letters, rub it against his clothing and then attract dust particles and small pieces of paper.

Valdemar Poulsen also loved to draw, and he had the ability to quickly and infallibly perceive and draw the characteristics in the different people he met. His school text books were always full of doodles in the margins – not with useful comments to the text but with caricature drawings of the teachers. When at Christmas time or before a summer vacation they wished to entertain the class it often happened that Valdemar Poulsen was called up to the black board and asked to draw for the amusement of the entire group. Often the teacher would go into the neighboring class to fetch the subject of an unusually successful caricature. He preserved this drawing ability and has drawn many excellent, well-resembling and characteristic portraits of various persons who left a special impression on him.

About schooling in Borgerdydskolen Poulsen writes, in 'Kroniken': 'When time came to select a future topic I opted for the linguistic-historical path and not the mathematic-scientific, as one might expect. The reason was simply that I had difficulties with mathematics probably because of an often-used expression 'It is easily seen that.... ', in parts of the text where the mathematics were particularly difficult. I would consequently draw the conclusion that I was worse in mathematics, worse than the case really was.'

Poulsen wrote, for that matter, about the linguistic-historic studies: 'I realize with pleasure the importance of the thus acquired knowledge about the old classic authors had on my development. And I am grateful for the lasting values of beauty I received from old Greek and Latin culture and thinking.'

He passed the students' exam with a top grade and his studies in philosophy with a top grade as well, and he commenced studies in medicine after his father's wish. He did not venture very far in that study but he did encounter a professor Julius Thomsen's enthusiastic lectures in chemistry. 'He never failed attendance at these lectures. Thomsen's authoritative and powerful personality, together with his witty and lively lectures, and the calm and unfailing confidence in carrying out the simplest lecture

experiments made a lasting impression on Poulsen. It clearly influenced his desire to become occupied with nature's sciences. And numerous are the small sketches of Thomsens characteristic face in Poulsen's textbook.' (After Holst [1]).

Poulsen wrote in 'Kroniken': 'Never before nor later did I as a nature scientific and artistic inclined student experience more enthralling lectures. Thomsen's rather grim and somewhat melancholic look disappeared on occasions, as when he advised the students of an upcoming experiment: 'Now my dear gentlemen will observe a rather lively reaction', and immediately thereafter the auditorium would resound with a thundering boom that more than woke up the sleeping worthless on the back rows,' (Author's translation.)

In the following months Poulsen studied for the entrance examination at the Technical University of Denmark, and worked as an apprentice with Frich's descendants. Poulsen covered this period very lightly in his Kronik: 'Destiny left me with a few but important scattered studies and I succeeded in a smooth emergency landing into the unnerving but also interesting institution KTAS – Københavns Telephone Company (this must have been around 1890; author). Here I received much encouragement from the approximately 10 year-older eminent mathematician and electrotechnician J.L.W.V. Jensen, not just through the power of the example but also through his great interest in physics and chemistry that often generated mutual sympathy and interesting conversations.'

Poulsen continues: 'Already before I came to KTAS did I meet *Mary Rasmussen* who later became my wife and invaluable co-worker. Her friends immediately became mine; among them were professor at the Polytechnic University S.C. Borch and his wife, in whose hospitable home we often came. Here I met for the first time the young polytechnic student P.O. Pedersen who later became important for my inventions and for myself. Professor Borch and his wife's charming manners should be emphasized at this occasion, they who loved everything that nature gave of beauty. Borch's comprehensive knowledge and acuteness measured up to his modest seclusion; he was a man of his home who found many applications for his great technical insight and practical sense – he was thus, already from the wet plates time one of the best photographers I ever encountered. When he went to students' examinations his wife would follow him to the door and plead: 'Please be gentle with the students.' This small detail characterizes the too early deceased woman's desire to know that others were happy, rather than affected by her husband's judgment of the students. He was undoubtedly as mild in his judgment as his objectivity and sense of justice permitted. The memoirs from the Borch home are among the richest and most beautiful for my wife and I, and also for P.O. Pedersen, who later married Mrs. Borch's younger sister who throughout life possessed the same mild mannered thinking and desire to make others happy.'

1. Inventions of recording machines

A mechanical phonograph had been invented by Edison in 1877, and worked very well with good sound quality for recordings lasting several minutes. The most desirable application for such a recording device was to serve as a telephone answering machine when no one was present to answer. The mechanical phonograph could not readily be connected to the telephone circuit since an electro-mechanical transducer was not available (see Ref. [2]). Another way of recording was being sought and discussed among the people at the telephone companies around the world, and of course also at KTAS where Valdemar Poulsen now worked. Poulsen's first plans were to develop an electrolytic phonograph of some sort and while working on this he came upon the idea of an electromagnetic phonograph. His first experiment was to draw a cross with a steel magnet on a piece of iron and then dip that piece into iron filings. When he verified that there were magnet poles at the end of each line in the cross he was convinced of the principle's validity [1].

The next experiment was, after Holst, that Poulsen tried to record speech on a rotating plate and here he used a round saw, but the experiment failed because the saw rotated too slowly. His first succesful experiment happened when he moved an electromagnet along a 1 m long steel wire suspended between two nails on a piece of wood. Later followed experiments with a wire wound on a cylinder. That was during a vacation in Vallerød, north of Copenhagen. It was necessary to determine optimal values for wire thickness, velocity, strength and distance of the magnets, and everything required speech tests. Like Edison used a favorite sentence 'Mary had a little lamb, a little lamb, lamb, lamb,' Poulsen used his favorite word 'Jacob'; the neighborhood's population must have wondered about this man who kept saying 'Jacob' to his equipment.

August 1898 is the date for the invention and issuance of patent for the first Poulsen Telegraphone, a drum recorder. A few months later Poulsen quit his job at KTAS and was now joined by P.O. Pedersen, a brilliant engineer with a very strong theoretical background. Absalon Larsen's [3] book about the Telegraphone has as subtitle 'and the inventor pair Valdemar Poulsen and P.O. Pedersen.' Poulsen and Pedersen were the best of friends, displayed excellent respect for one another and worked together for many, many years. But Larsen's subtitle is ambiguous: Pedersen assisted Poulsen in many experiments, evaluations and discussions, but Valdemar Poulsen was clearly the inventor [4]. Pedersen was a brilliant engineer/professor with theoretical and

Fig. 2. Painting of Valdemar Poulsen and P.O. Pedersen, painted by Knud Larsen 1915 (Frederiksborg Museum).

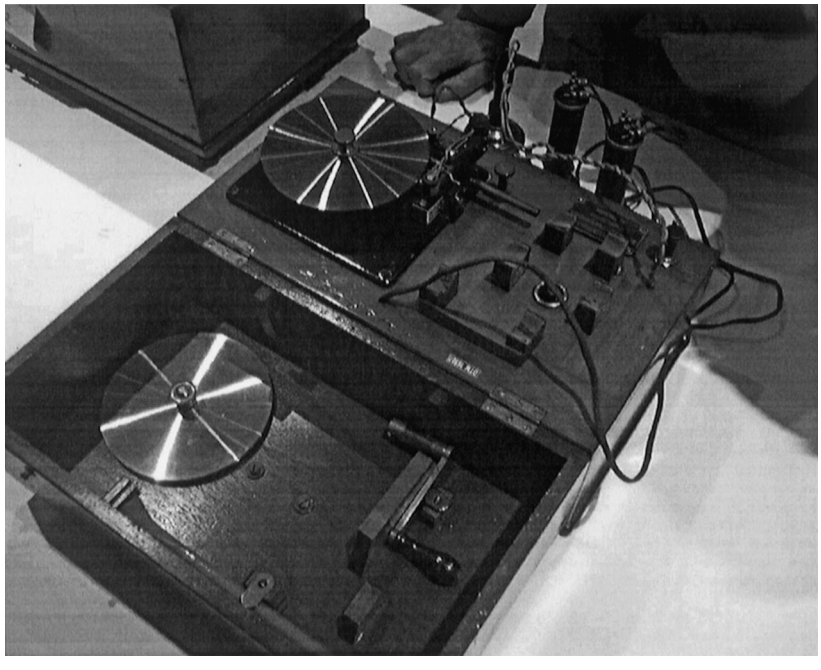

Fig. 3. Disk Recorder (Denmark's Technical Museum).

mathematical insight where Poulsen came up too short, even though they shared certain patents and Pedersen had some of his own (Fig. 2).

Poulsen's first patent which was applied for on 1 December 1898 and issued 31 October 1899, describes two devices. One is a drum recorder where a steel wire is laid

into a spiral-shaped groove on a cylinder surface. The cylinder is rotated with a constant number of revolutions by a clockwork or a small motor. The write and read magnet is mounted on a carriage that is guided by a steel shaft parallel with the cylinder. The magnet's pole shoes rest on each side of the wire and thus pulls the magnet along when the cylinder rotates. In this way the magnetization is laid down 90° to the travel direction. Another recording device used a flat steel ribbon that was wound from one roll to another.

Neither device succeeded in providing sufficient record/play time for an answering machine which unfortunately was the device that the inventor, the constructors and financiers all were pursuing. All the applications we know of today were nonexistent then: sound, video and computer.

Companies were formed and/or entered into partnerships with, to produce Valdemar Poulsen's invention first in Germany and, later in the United States of America. The commercial success was, mildly speaking, dismal, at the same time it provided a large amount of admiration for Poulsen and a worldly life style. One last attempt at commercialization of the Telegraphone was done by developing a disk version, see Fig. 3. At first a disk diameter of 13 cm was chosen to offer the convenience of easy mailing. The playing time did not improve much though, and it was decided to increase the diameter. Now the force required to turn the disk went up and with it other things changed disfavorably. The entire development and associated business actions are covered in a study by Clark et al. [5] in a small book reprinted for this conference by ATV in Denmark (Danish Academy of the Sciences). See also articles in *Magnetic Recording*, *The First Hundred Years* [6].

Neither Valdemar Poulsen nor P.O. Pedersen made much financial gain on the Telegraphone and they did, as a matter of fact, lose interest in the magnetic recorder projects around 1902. Other technologies had by then caught Poulsen's attention and interest, this time by projects on transmission of signals. And P.O. Pedersen took up work as a Professor at the Polytechnic University in Copenhagen, eventually to become its Dean.

2. Invention of the arc generator

At the turn of the century cables were required to transmit signals over large distances and the signal would lose quality and strength. Wireless transmission had been implemented by Marconi's invention in 1895–96. It used a spark generator and was only capable of transmitting Morse signals, not continuous signals as speech or music. It operated by generating a spark in the small air gap in an induction apparatus and its associated electromagnetic wave would propagate with the velocity of light.

The generated electromagnetic impulses covered a very broad frequency spectrum so the Marconi transmitters were unable to transmit on single separated frequencies. When we later on learnt about the naval battles during the First World War we could understand the confusion among the British units that used Marconi gear and the better equipped German unit that used tuneable Poulsen transmitters and receivers that neatly sorted out the communication channels.

Poulsen's new invention was capable of continuous amplitude modulation of the transmitter signal which was impossible with the spark generator. The prerequisite for Poulsen's invention was a tuned, oscillating circuit that was used in combination with the electric arc light source. This singing arc was under investigation by the British physicist W. Duddell who had added the capacitor in parallel with the arc, and later an inductor. During one demonstration Duddell played 'God Save the Queen' by using a keyboard with various capacitors.

With declining interest in his Telegraphone Poulsen became fascinated by this electric circuit. He probably found his inspiration from reading an issue of 'The Electrician' from December 1900 with an article by Duddell describing a simple tuned circuit wherein the circuit is broken by a continuous arc. Poulsen started experiments in his house, leaving the Telegraphone work, and in 1902 he came upon the idea of holding a spirit-lamp under the arc in the circuit, being formed by two horizontal pieces of carbon. This had an immediate great effect by increasing the circuit currents, in particular the AC-component. He went on to perform experiments where the arc would burn in a hydrogen atmosphere, and he consequently filed his arc generator patent in 1903.

Poulsen kept on with experiments. In one case he placed a magnet near the arc so it moved upwards. This had a significant effect, and was added to subsequent patent applications. So the key elements in his arc generator patents are the hydrogen atmosphere and the magnetic field.

Much experimental work continued and fabrication of Poulsen transmitters (Fig. 4) soon took over the earlier Marconi designs. This success lasted until 1920 when the deForest electronic vacuum tube took over from the arc element. Signal reception and subsequently the use of crystal detectors followed and soon radio telephony and large-scale transmission and reception in homes followed.

3. The autumn of Poulsen's life

Valdemar Poulsen received a Gold medal from the Society of Sciences in Denmark in 1907. This was probably the zenith of his technological achievements and he was in the following years busy with inventions, new constructions and tests. There were patent questions to

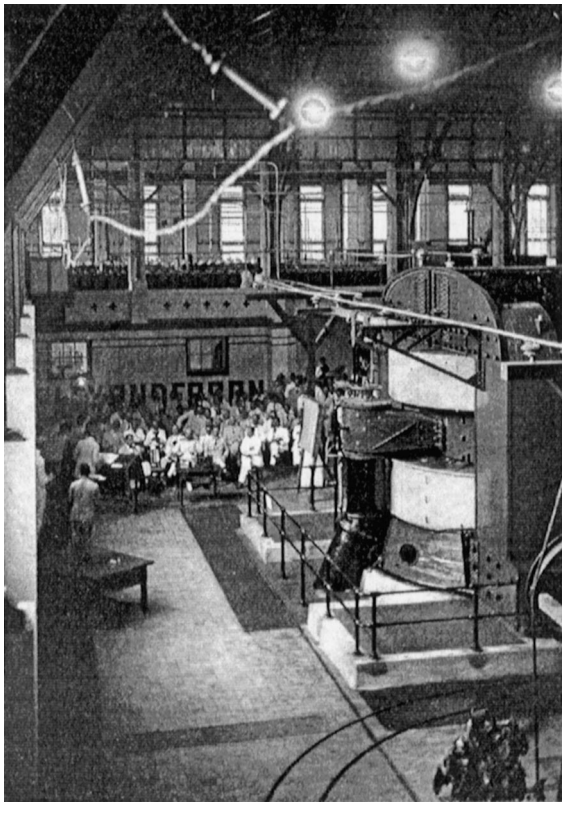

Fig. 4. Poulsen 3600 kW 'Malabar' Transmitter on Java used for transmitting to the Netherlands [3].

resolve along with business matters. But from 1910–1912 his inventor activities were pretty well over and he lived thereafter as a very involved and interested private person.

'With a unique charm Poulsen could interest a small, closed group. Here his impulsive and inciting personality came into full bloom. He could keep the interest of those present by his brilliant, bubbling wit that ignited a firework of comments on everything between Heaven and Earth. Many topics were remote from technology – but they were always original, at time paradoxical, considerations that evoked afterthoughts in the listeners. He was, in such cases, the center of the party...' (After Holmblad [7]).

Poulsen received several recognitions:

In 1909 he was nominated to Dr. phil. H. c. of the University of Leipzig.

In 1913 he received the Danish Gold medal of Merit.

In 1914 Poulsen was accepted as Member in The Danish Academy of Sciences.

In 1923 and 1939 he received the medals of Commander.

In 1929 he was nominated to Dr. technicis at the Polytechnic University of Denmark.

In 1936 he was Vice President of The Institute of Radio Engineers.

In 1919 Valdemar Poulsen (Fig. 5) moved from St. Blichersvej in Frederiksberg to Maltegaardsvej in Gentofte, where he lived until his death in 1942. There he built a laboratory in the basement where he toiled with various experiments. There were always strange rumors about some new experiments and of course expectations that he once again would surprise his contemporaries with new inventions.

P.O. Pedersen, reported in some notes from 1920 that 'the collaboration with Valdemar Poulsen resulted not only in invaluable experiences in various disciplines and a good profit but it also resulted in a close and genuine friendship between us.

The co-work with Poulsen often placed me in front of problems whose solution demanded a considerable physics–mathematics knowledge. In 1900 I therefore started studies in Mathematics and in particular Physics and have since then – with more or less energy – continued these studies.' It should be noted that P.O. Pedersen was educated as a structural engineer.

An engineer Chr. Kielland-Brandt writes (translated, source Larsen): 'Over the years it became a pleasant sight to see Pedersen and Poulsen, these two great contrasts, be so invaluable to each other. Their friendship started between their wives, and through many years the two friends were daily lunch customers at one or another café in Copenhagen. As the business matters regarding Poulsen's inventions entered a more passive phase then Poulsen started to cultivate his hobbies. Pedersen continued his scientific works and with unceasing diligence aiming at the technological–social goals he had set.

As the two men aged their paths separated somewhat, and while Poulsen of a whole heart was pleased with the friend's luck and progress it could happen, that he totally without Pedersens fault felt placed in the shadow. But their friendship endured, which came beautifully to show around Poulsen's 70 years birthday and also by their many lunches that lasted on as long as they lived.

As an elder man Poulsen was always a welcome guest wherever he went. He had every social accomplishment and he was often, at his high age, the center of the party with his roguish, sometimes teasing wit, his quickness and fascinating self irony that on occasions expressed itself through a smile and a particular chuckle when he did not have a riposte ready. When something keenly was on his mind he would break into stuttering. He was born left-handed; ordinary writing he did with his right hand but he preferred to draw with the left hand, which he would also use when he wrote numerals. Poulsen's power of observation sharpened his sense for the beauty and greatness in nature in which connection one traces his relationship to both the mother's and the father's side. We can mention his mother's brother, the painter J.H. Brandt and the half-brother, the author Knud Poulsen.'

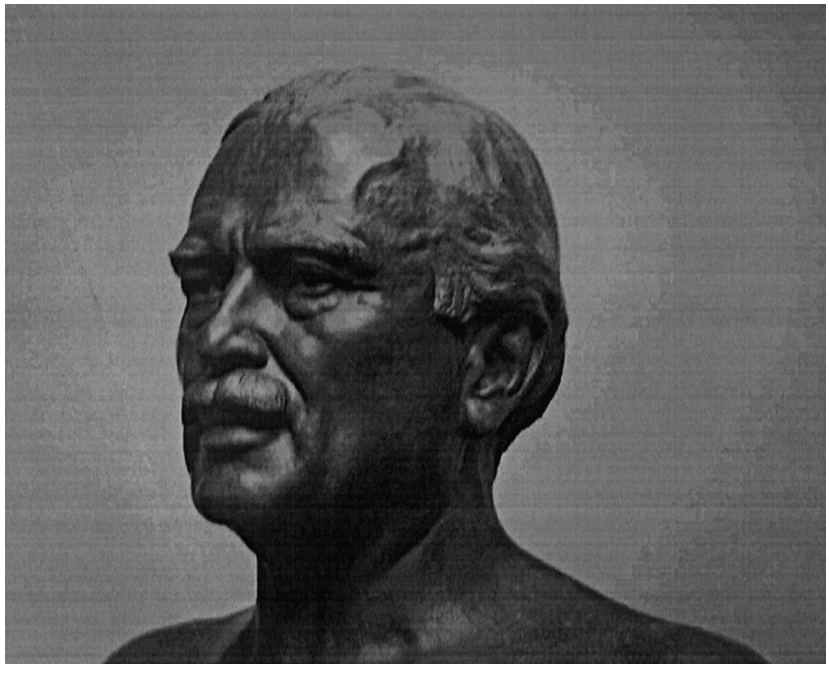

Fig. 5. Bust of Valdemar Poulsen, located in The Danish Engineering Society's Building in Copenhagen (courtesy of the Poulsen Family Archives [8]).

Valdemar Poulsen experienced only the first couple of years of the second world war. He interpreted the war news in the most optimistic way and he would scold friends when they expressed concern over what the intense German advances could lead to.

Valdemar Poulsen was, with his many rich faculties and oddities a remarkably charming person, that in some noticeable way made his influence to bear by merely being there.

Acknowledgements

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